Interacting Galaxies

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Introduction

With the images seen in the popular media, it is easy to believe that galaxies are isolated bodies in the Universe. However, most galaxies are found in groups and clusters and a not uncommon occurrence is to have one galaxy interacting with another. These interactions tend to change the morphology, or shape, of the galaxies involved, rip out massive tidal tails of stars and gas and initiate star formation as the gas in the galaxies is compressed.

Galactic interactions take place over millions of years so this galactic dance cannot be observed in its entirety. However, observations of different interacting galaxies can be used to build up a sequence of how the interactions may have proceeded. Supercomputer simulations can also be used to investigate how galaxies interact.

Complementary resource material for the Interacting Galaxies Investigation can be found at the UK Faulkes Telescope **Observing Interacting Galaxies** and **Crashing Galaxies** websites (see the **External Resources** section for links).

Downloads

From here you can download everything you need to get you started with the Interacting Galaxies project.

1. Download and install IRIS

You can download **IRIS** from the **IRIS home page** and install, or simply use the version provided in this package. You may need to select the file **SETUP.EXE** to start the installation. **Note:** The default install directory is **C:\iris**. You will probably want to change this to **C:\Program Files** or something similar. The installation program asks you for this directory. Once installed, you may want to **right-click** on **iris.exe** to create a shortcut which you can then drag to the desktop or other appropriate place. Follow the instructions for **Configuring IRIS** to set your working path to **C:\data** (or preferred directory).

2. Downloading Practice / Archive Data

One of the best ways to learn how to use IRIS and how to analyse your interacting galaxies is to practice on some real data! Please download the data included in this package from the Faulkes Telescope North for any or all of the six sets of interacting galaxies. Each set contains a red (R), blue (B), and green (V, or visual) image. Save the files to your hard drive in the directory **C:\DATA** (or preferred directory).

Selecting Interacting Galaxies to Observe

This section is only relevant if you plan to sign up for the Faulkes Telescope Project in order to make your own observations. It is not necessary if you are only using the archive data available from the **Downloads** section.

1. Download the Planner.

Download the **Observation Planner for Interacting Galaxies** (Excel file) from the Faulkes Telescope North project page on **Interacting Galaxies**.

2. Obtain a list.

Input the **date** you plan to take your observations in the **Visibility Calculator**, as in Figure 1. In this case the observing date is set to the 1st April, 2007.

FAULKES TELESCOPES OBJECT VISIBILITY CALCULATOR

Written by Richard Beare, Institute of Education, University of Warwick
for the Faulkes Telescope Project 15th November, 2004

DAY dd 1
MONTH mm 04
YEAR yyyy 2007

Use Summer time in the UK

INTERACTING GALAXIES

Objects visible for a WHOLE half hour slot by in Hawaii and Australia
shown by H and A - dashes mean never visible from the location.

IMPORTANT NOTE: also check lower down table for entries

no	Arp no	Alternative name	Distance Mpc	Size arcmin	Mag	Further info	N O W	4:00	4:30	4:30	5:00	5:00	5:30	5:30	6:00
1	327	Hickson 34		2.6		chains of galaxies		H	A	H	A	H	A	H	A
2	303	IC 563 + 64		3.5		uncertain, probably filaments		H		H		H		H	
3	321	Hickson 40		2.6		groups of galaxies		H		H		H		H	
4	275	NGC 2881		2.1		interacting		H		H		H		H	
5	94	NGC 3226 + 27		10.4		elliptical companions		H		H		H		H	
6	270	NGC 3395 + 96		3.5		connected arms	---		---	H	---	H	---	H	---
7	107	UGC 5984		3.5		connected to spirals	---		---	H	---	H	---	H	---
8	105	105 B 5.2 + B		5.2		connected to spirals						H		H	
9	301	UGC 6204		2.6		uncertain, probably filaments						H		H	
10	322	Hickson 56 (part)		2.6		chains of galaxies	---		---		---	H	---	H	---
11	296	MCG+10-17-005 + comp		3.5		long filaments	---		---		---	H	---	H	---
12	299	NGC 3690		3.5		uncertain, probably filaments	---		---		---	H	---	H	---
13	280	NGC 3789 + A		3.5		interacting	---		---		---	H	---	H	---
14	294	NGC 3786 + 88		10.4		long filaments	---		---		---	H	---	H	---

Figure 1: Observation Planner.

This returns a list of the galaxies visible at various times of night from Hawaii and Australia. It also gives you a short description of the interacting galaxies in the column **Further info** and the size of the interacting galaxies in the column **Size arcmin**.

3. Select potential galaxies based on size.

The field of view of the Faulkes Telescopes is approximately 5 arcminutes. Therefore, in order to fill your image with the interacting galaxies and make sure each galaxy is large enough to be studied visually, you should choose those interacting galaxies with a **Size arcmin** of around 5. If **Size arcmin** is greater than 5, there is an added level of complexity as you will need to mosaic the images. The galaxies **NGC3395 +96** with a field of view of 3.5' are selected for this example.

4. View the galaxies in the Aladdin Viewer.

To see what you can expect from your observations, you can view online images of your galaxies. This is particularly useful if you would like your students to study particular types of interacting galaxies.

Go to the **SIMBAD Astronomical Database**, as in Figure 2, input the identifier (in this example: ngc3395) of your selected interacting galaxies in the **Identifier field** and click the **Submit Id** button.

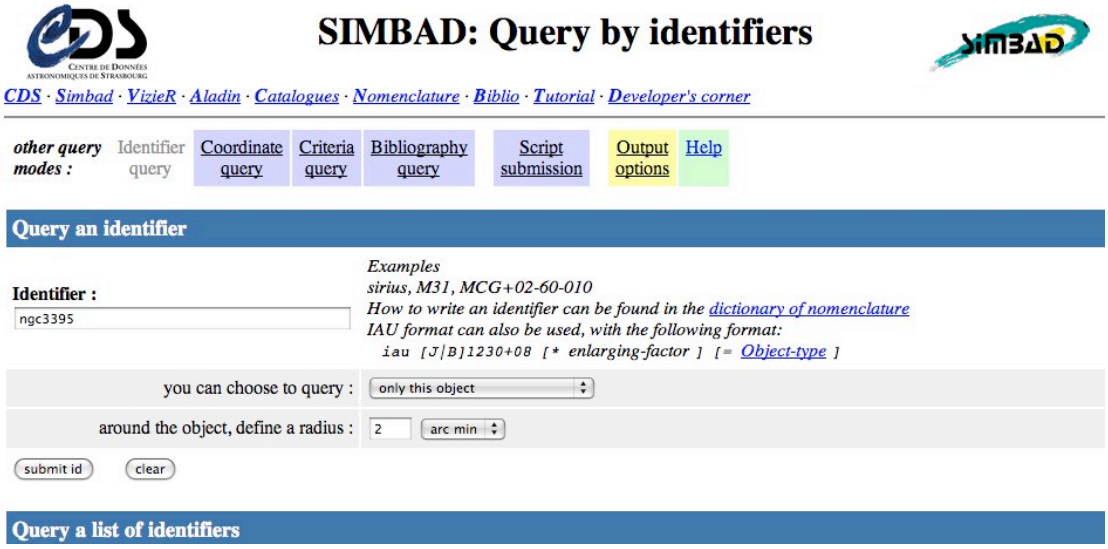

Figure 2: SIMBAD query.

This returns a page with a large amount of data on the object you have just identified. Scroll down the page until you see the section labelled **Plots and Images** as in Figure 3. Click on either the **Aladdin Previewer** or **Aladdin Applet** buttons to view your object.

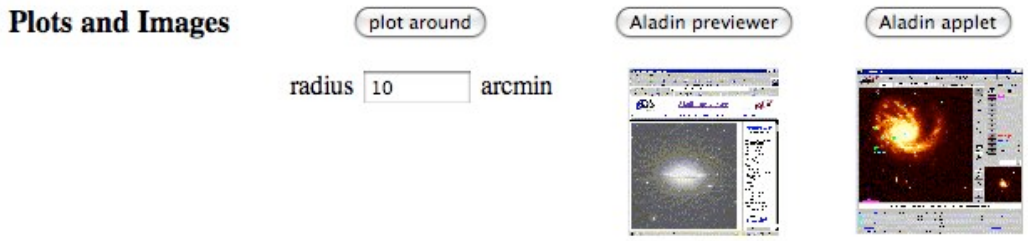

Figure 3: SIMBAD results.

The **Aladdin Previewer** is faster and returns a simple image of the area. As can be seen on the right-hand side of Figure 4, the **Size and Definition** is 14'.1 x 14'.1, much larger than the 5' x 5' of the Faulkes Telescope field of view. This means that the image downloaded by Aladdin is much larger than what you will see with the Faulkes Telescope.

The **Aladdin Applet** is slower but allows you to interact with the returned data and reduce the field of view to something similar to what you would see with the Faulkes Telescopes. Figure 5 shows the full field of view of approximately 13' x 13' returned by the Aladdin Applet. However, you can adjust the field of view by altering the **Zoom** level on the right hand side from **2/3x**.

Adjusting this to be **Zoom = 2x**, as in Figure 6, you now have a field of view of approximately 4.3' x 4.1' which is approaching that of the Faulkes Telescopes. In this case, the images from the Faulkes Telescopes would show slightly more than what you can see here. You can see from this image that NGC 3395 is a good example of a pair of interacting galaxies to observe as the pair almost fills the field of view.

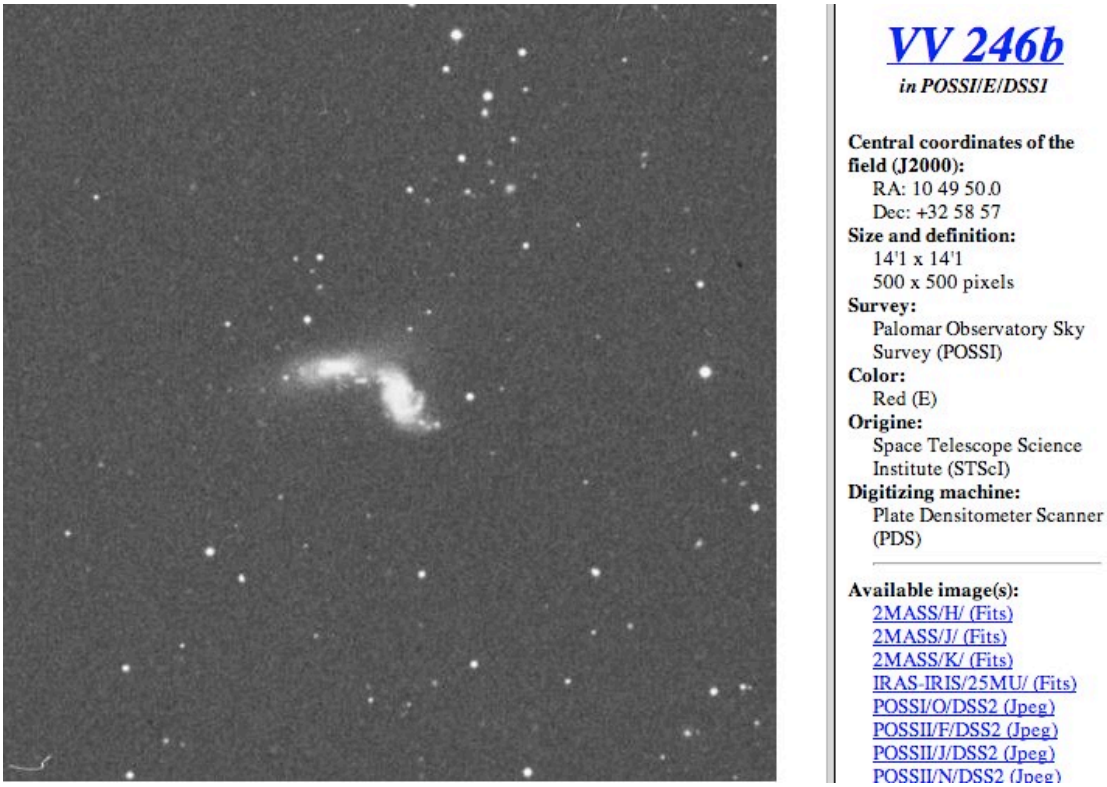

Figure 4: Aladdin Previewer. **Size and definition** shows the image size.

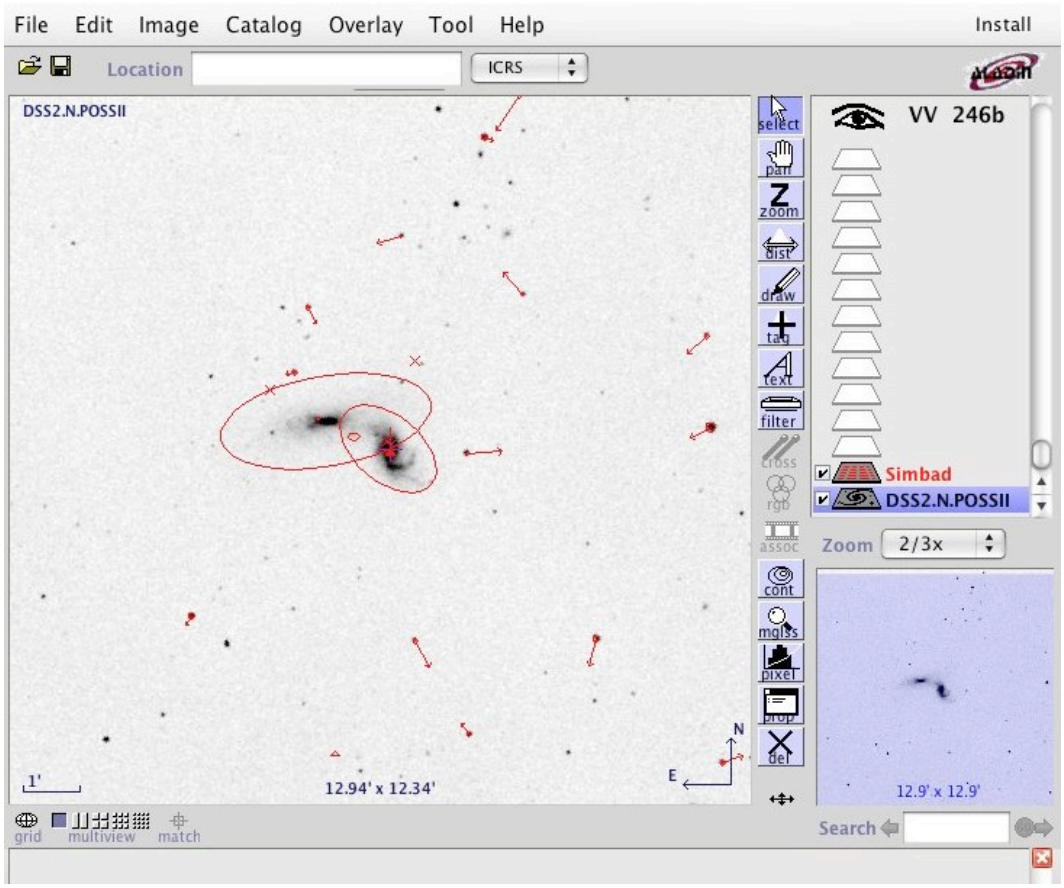

Figure 5: The Aladdin Applet. Image size is shown at the bottom of the image.

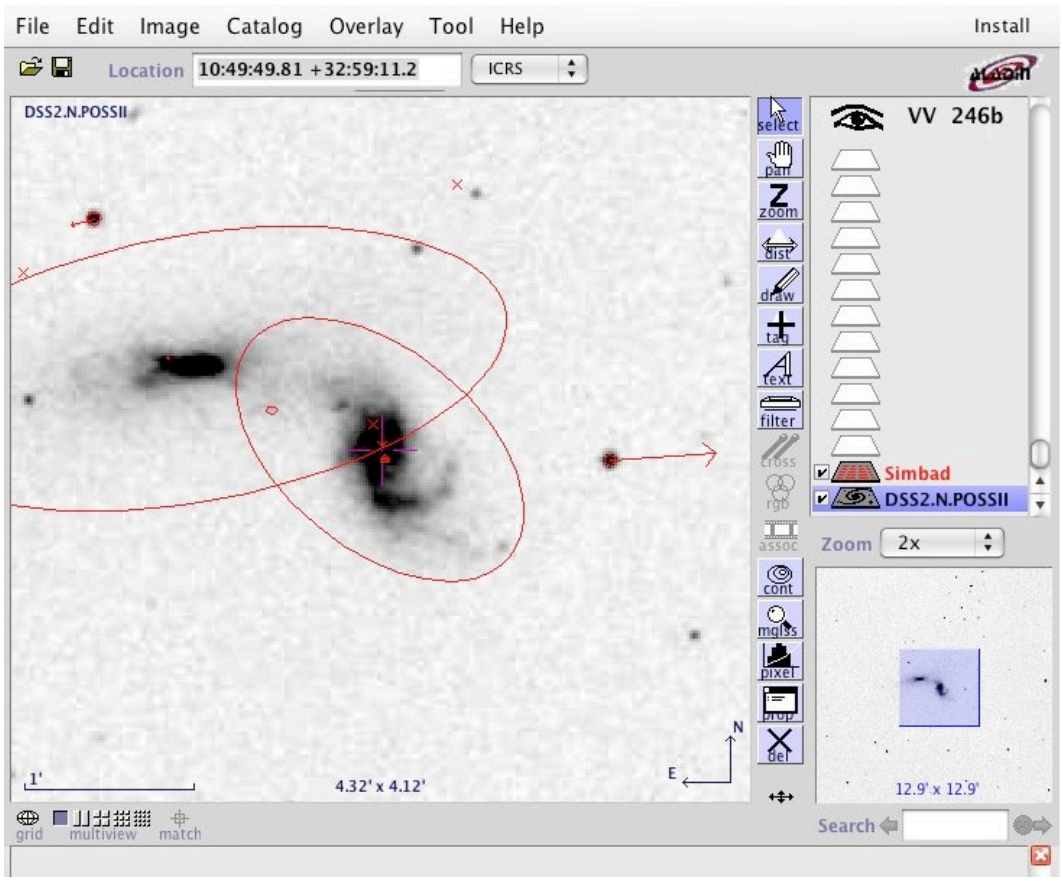

Figure 6: Zoomed Aladdin Applet.

Measuring the sizes of the Galaxies

This section can be quite mathematical so you might want to check before assigning this exercise to your students. A way around this is to determine some of this for yourself in advance and give students some of these numbers.

1. Open the image.

Open **IRIS** and **Load the V image file** for the interacting galaxies you wish to study. Adjust the threshold levels until you think you can discern the edges of the galaxies, or click on **View » Modified Equalization**. NGC 3395 is used for this example.

2. Mark the edges of the galaxies.

Students must decide where they think the edge of each galaxies lies. There may be significant differences depending on the threshold or display settings each student has decided to use and this can be a topic for discussion in class: "How do you decide where the galaxy finishes?"

Select **Analysis » Select Objects…**

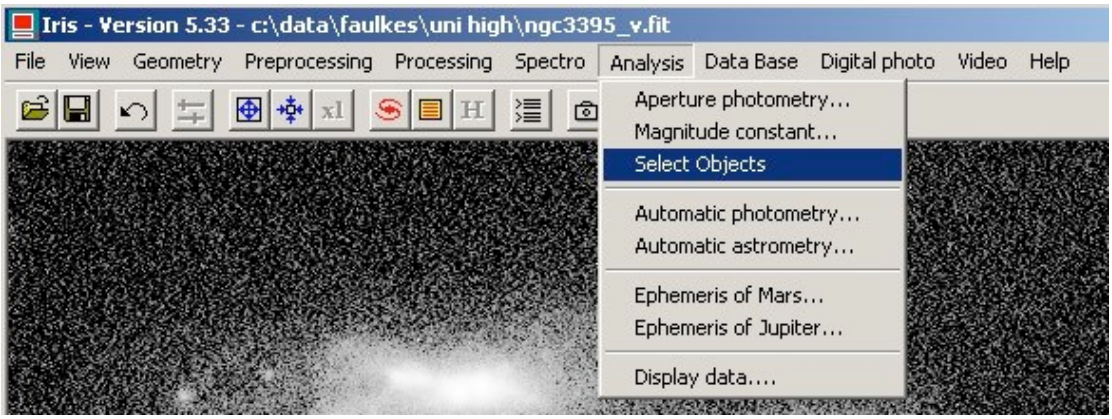

Figure 7: Select Objects.

The cursor will change shape and an **Output** window will pop up on the screen. Click at one edge of one of the galaxies and the x,y-coordinates will appear in the **Output** window. Click at the other edge of the same galaxy and these x,y-coordinates will also appear in the **Output** window.

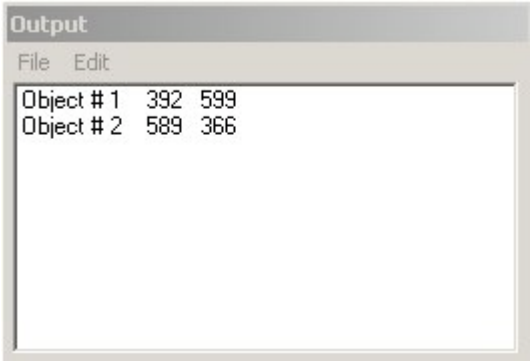

Figure 8: Coordinates.

3. Determine the size of the galaxy in pixels.

Using the Pythagorean theorem, these x,y positions can be used to determine the apparent diameter of the galaxy in pixels.

$$\text{Size in pixels} = \text{sqrt}\,[(392 - 589)^2 + (599 - 366)^2]$$
$$= 305.1 \text{ pixels}$$

4. Determine the size of the galaxy in arcseconds.

Each pixel of the Faulkes Telescope images corresponds to a size of 0.27837 arcseconds. This is set by the properties of the CCD camera and the focal length of the telescope.

$$\text{Size in arcseconds} = 0.27837 \text{ arsec/pixel} * 305.1 \text{ pixels} = 84.9 \text{ arcseconds}$$

5. Find the distance to the galaxy in Megaparsecs (Mpc).

Open the **SIMBAD Database Query:**
http://simbad.u-strasbg.fr/simbad/sim-fid
Type the name of the object into the **Identifier** section and select **Submit ID**, as in Figure 2.

This will return a page of basic data on that object as in Figure 9.

Figure 9: SIMBAD query results.

Look up the **cz** value for the object under the *Radial velocity/redshift/cz* section. In this case it is 1634.0 km/s.

The distance to the galaxy in Mpc can now be found using the following equation:

$$D\ (\text{Mpc}) = cz/H_0$$

where H_0 is the Hubble constant which we will set at 70 km/s/Mpc.

6. Determine the size of the galaxy in Mpc using the small-angle formula.

The appendix, taken from
http://cosmos.phy.tufts.edu/~zirbel/laboratories/AstrometryPreLab.pdf,
explains the derivation of the small-angle formula. You may also refer to Part 1, Step 6 of the **Age of a Planetary Nebula** teaching module for further explanation.

The calculation for the above galaxy would be:

Size in Mpc = [(Dist to gal in Mpc) * (gal size in arcseconds)]/ 206265 arcseconds

For NGC 3395:

Distance to galaxy = 23.3 Mpc (calculated in Step 5.)
Size in arcseconds = 84.9 arcseconds (measured in Step 4.)
Size in Mpc = (23.3 * 84.9) / 206265 ≈ 0.0096 Mpc = 9,600 pc.

7. Convert parsecs into light years.

1 parsec ≈ 3.26 light years
Size of NGC 3395 in light years ≈ 31,000 light years.

You may wish to compare this with the size of the Milky Way, which is 100,000 light years across.

Making a Colour Image in IRIS

Another activity you might like to undertake with your students is to create a colour image with your data. Not only will you produce a stunning colour image, you can use this exercise to teach students about what happens when different coloured light combines. It can also be used (depending on the data) to show that stars and different regions of galaxies have different colours and lead on to a discussion of why this is so.

Note: In order to do this, you **must** have 3 images of the same object, one taken through the B filter, one through the V (green) filter and one through the R filter.

1. Make sure your image filenames have the correct **.fit** extension. If not, simply rename **image.fits** to be **image.fit**

2. Make sure your image filenames contain only lower-case letters. If your files have capitals in the filenames, simply rename them using lower-case letters.

3. Start IRIS by double-clicking on the program icon.

4. Load and superimpose the images taken through the B, V and R filters.

Select **View » (L)RGB...** You need to put the filename (drop the .fit extension) in the appropriate box and click **OK**.

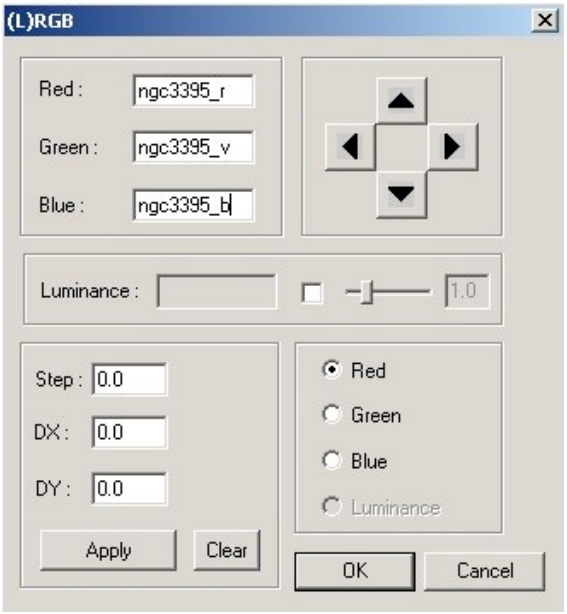

Figure 10: (L)RGB settings.

This will load and superimpose the images. The screen will probably appear black initially and in order to see the resultant image more clearly, click **Auto** in the **Threshold** window.
Note: DO NOT at any point click on any of the four coloured buttons in this **Threshold** window. Alternatively, you might want to play with the sliding bars in the **Threshold** window to obtain a clear view of the objects in the image. (Note: the **Threshold** window sets the brightness at which the pixels in the image are shown to be white - in this case at a brightness of 32767 - and the brightness at which the pixels in the image are shown to be black - in this case a brightness of 0).

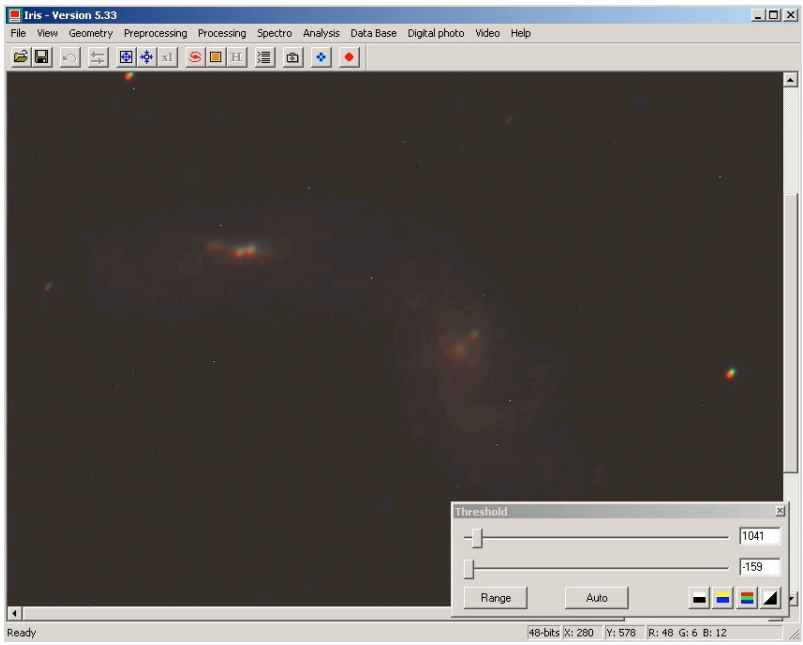

Figure 11: Stacked images.

If you look closely at the stars (rather than the galaxies) in this superimposed image, you will be able to distinguish the image of the stars taken through the red filter (red dots), the image of the stars taken through the visual filter (green dots) and the image of the stars taken through the blue filter (blue dots). How much the telescope has moved between each image will determine how closely aligned the stars are at this stage. You may also notice that the image itself has a general hue (i.e. the background is not black - in this case it has a reddish hue). This will depend on how much light was let through each filter (in this case, the light coming through the red filter was stronger than that coming through the green or blue filters) and may not be the case if you have previously selected **Modified Equalization** (refer to the **Making a Colour Image** teaching module).

You now need to shift each of these individual images (red, green, blue) so that they line up on top of each other. This process is quite subjective but you should be able to obtain a reasonable result.

5. Line up the images.

Select **View » (L)RGB...**

Panel A indicates which image you are manipulating (red, green or blue). **Panel B** is the controller where you move the image. The **Step** field in **Panel C** is where you indicate by how much you want the image to move at once.

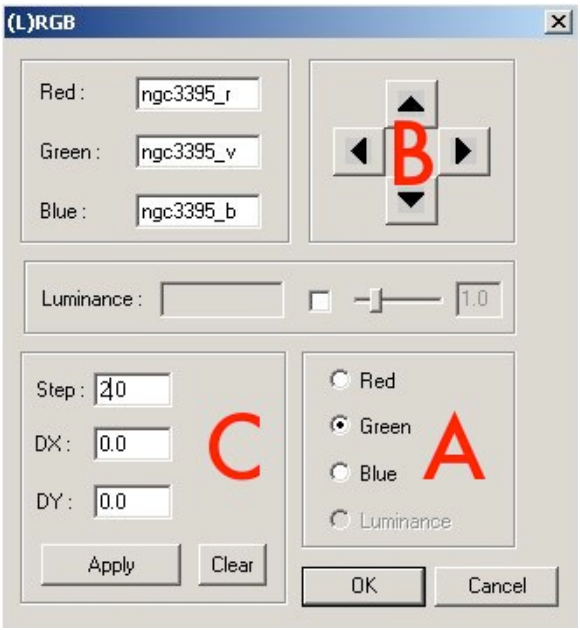

Figure 12: Control panel.

Start with the visual (green) image (**Green** is checked in **Panel A**) and try to align it with the red image. Start with a coarse adjustment of 2 pixels (input 2.0 into the **Step** field in **Panel C**). Now, using the controls in **Panel B**, move the green image until it lines up better with the red

image. What you are trying to do is make the stars round and their centres white (when you combine red, green and blue light - you end up with white light). You will need to adjust the **Step** to be much smaller as the alignment improves. Repeat this for the **Blue** image. Do not click **OK** until after you have completely finished lining up the images.

Once you are satisfied with your alignment, click **OK**.

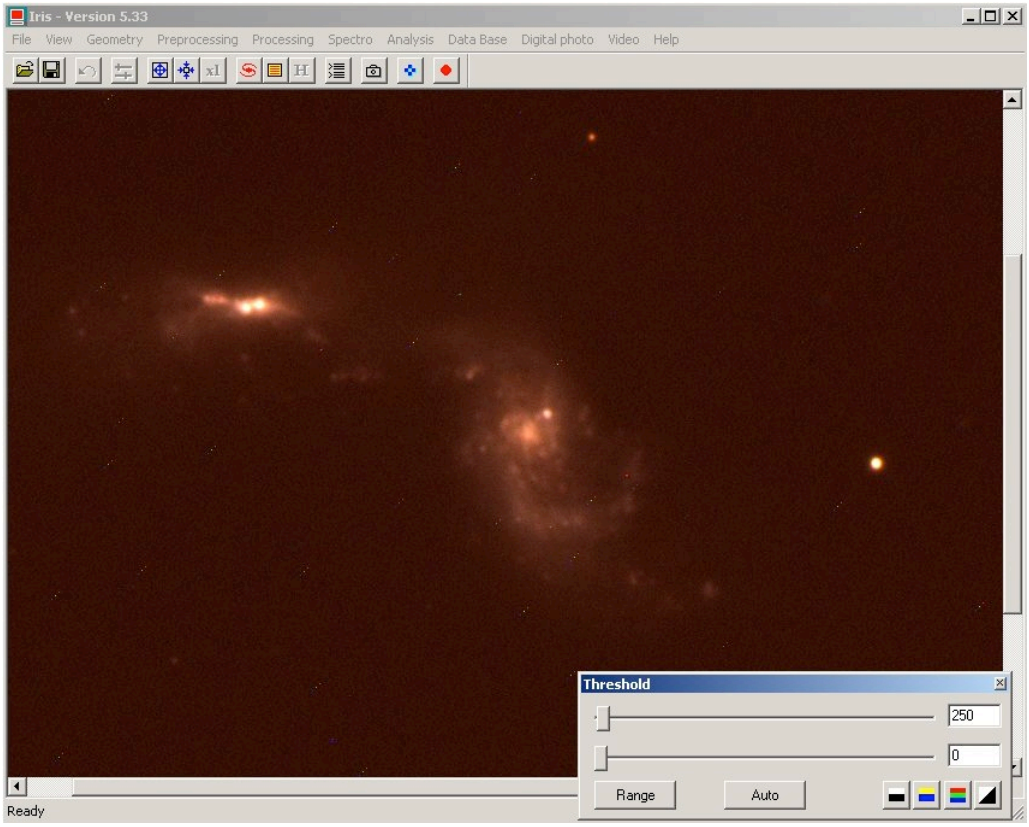

Figure 13: Aligned!

You will notice in this example that the stars have a reddish ring around the outside. The red images are slightly larger than the others. This may be due to observing conditions, different exposure times for the different coloured images or variations in the transmission of light through the different filters. Unfortunately, there is not a lot you can do about this.

6. Adjust the White Balance.

In an effort to eliminate the reddish cast the image has, select **View » White Balance Adjustment...** Here again it's a matter of playing with the controls until you achieve the look you want, as in Figure 14. You may also want to play with the **Gamma Adjustment**, **Contrast adjustment** and **Saturation adjustment** under this **View** menu. There is no hard-and-fast rule about how to make the image look its best, it really is a matter of you tweaking the controls. It's best to be able to see your galaxies as you are making the adjustments. You may also wish to refer to the **Making a Colour Image** teaching module for more information on other display options, but before making further changes, go to the next step to save your image.

7. Save your colour image.

Once you are satisfied with your image and you are ready to save it, select **File » Save...** This gives you multiple options for your save format. If you want to use the coloured image in IRIS (e.g. to make a mosaic out of several images) then you need to select .pic format (see Figure 15). Otherwise, you must save it in a format compatible with your other software (e.g. tif, jpg). **DO NOT** save it as a FITS file or your work will be lost.

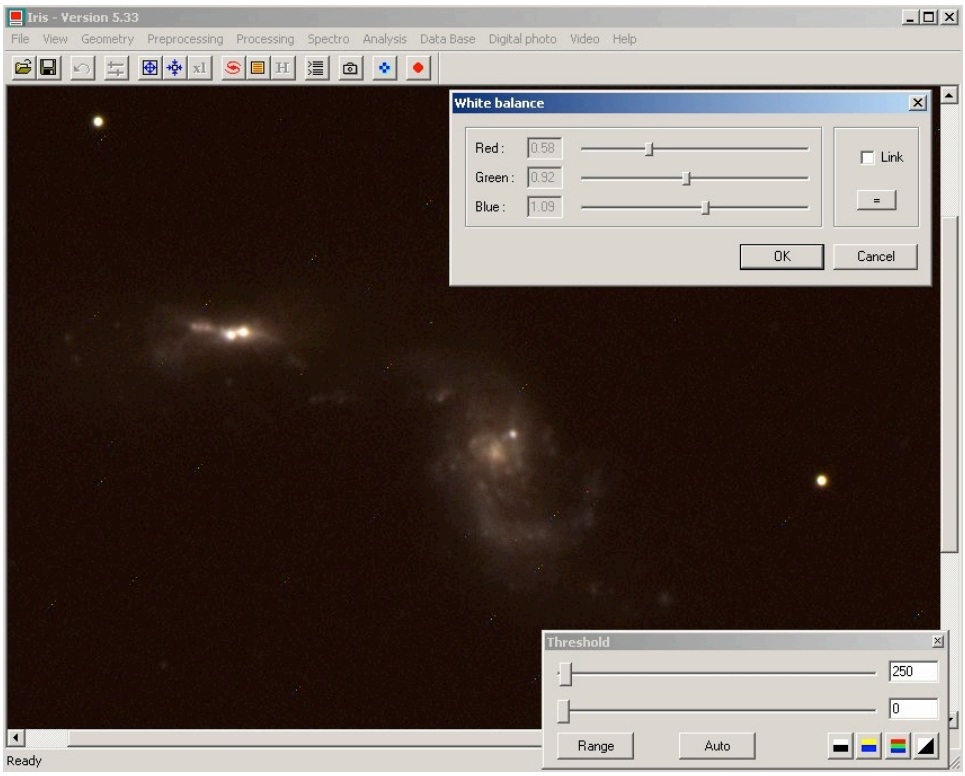

Figure 14: Adjusting the white balance.

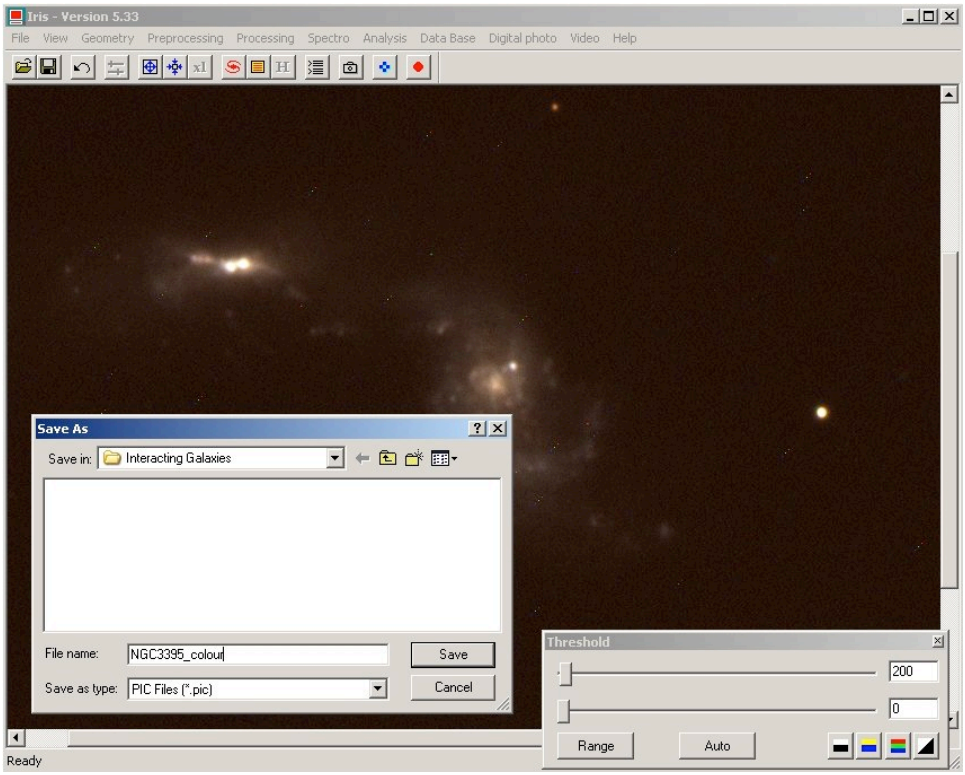

Figure 15: Saving your image.

External Resources

Before starting your investigation or once you have analysed your images, you might want to consider the following resources:

Galaxy Collision: Multi-media presentations from HubbleSite on galaxies and their collisions.

http://hubblesite.org/explore_astronomy/cosmic_collision/

Cosmos: Swinburne University's online astronomy encyclopedia has many articles that should be appropriate for a high school audience.

http://astronomy.swin.edu.au/cosmos/

Crashing Galaxies: This project from the Faulkes Telescope UK site uses the Galaxy Crash Java applet (http://burro.astr.cwru.edu/JavaLab/GalCrashWeb/) to allow students to collide their own galaxies. It contains teacher notes and student worksheets to guide you through using the applet.

http://faulkes-telescope.com/education/galaxies/crashing_galaxies

Observing Interacting Galaxies: This project from the Faulkes Telescope UK site is a straightforward project to image a number of interacting galaxies in colour, and then to identify different features visible in the images. It contains worksheets and other resources.

http://faulkes-telescope.com/education/projects/galaxies/observing_interacting_galaxies

Galaxy Interactions: Supercomputing simulations of galaxy interactions from the Hayden Planetarium. A short explanation accompanies each simulation.

http://haydenplanetarium.org/resources/ava/category/?category=G

Gravitas: Slow-motion simulations of galaxy collisions of various types. Information is provided on each of the simulations.

http://www.galaxydynamics.org/

SIMBAD Astronomical Database: Obtain data and images of galaxies.

http://simbad.u-strasbg.fr/simbad/

The IRIS home page: This page contains many tutorials and you can also download the IRIS User Manual.

http://www.astrosurf.com/buil/us/iris/iris.htm